2-10-1981

Eye protection for use in mountaineering

Michael Ernest Heil

Pacific University

Eye protection for use in mountaineering

Abstract

Approaching the problem of what constitutes an adequate pair of mountaineering glasses a look will be taken at what needs protection, why and how this is best accomplished. Characteristics to be expounded upon range from a physiological consideration, to electromagnetic considerations, to lenses (glass, plastic, contact), to frames, to several miscellaneous parameters. With a knowledge of these characteristics a person could readily identify an excellent pair of mountaineering glasses.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Jurgen R. Meyer-Arendt

Subject Categories

Optometry

THESES
OPT
Heil, M E

Eye Protection For Use In Mountaineering

By

Michael Ernest Heil

B.S., University of Nebraska, 1977

Faculty Advisor

Dr. Jurgen R. Meyer-Arendt

A thesis submitted to the Faculty of the College of Optometry of Pacific University in partial fulfillment of the requirements for the degree of Doctor of Optometry 1981.

Date: February 10, 1981

Michael Ernest Heil

Michael Ernest Heil

Jurgen R. Meyer-Arendt

Dr. Jurgen R. Meyer-Arendt

TABLE OF CONTENTS

Abstract

Approaching the problem of what constitutes an adequate pair of mountaineering glasses a look will be taken at what needs protection, why and how this is best accomplished. Characteristics to be expounded upon range from a physiological consideration, to electromagnetic considerations, to lenses (glass, plastic, contact), to frames, to several miscellaneous parameters. With a knowledge of these characteristics a person could readily identify an excellent pair of mountaineering glasses.

Eye Protection for Use in Mountaineering

Many activities require eye protection against the harmful effects of sunlight. On the commercial market there are numerous types of eyewear that protect against excessive effects of solar irradiation. However, due to the fact that there are many types of such glasses available, it is difficult, at least for the layperson, to decide which eyeglasses are better than others. In this paper I have collected characteristics that should be taken into account when selecting glasses for use in mountaineering.

To evaluate a pair of glasses for a specialized function, several aspects need to be looked at. The first is concerned with why eye protection is needed. The second is how these requirements are best met. In addition, lenses, frames and other aspects must be considered.

Consideration of Sun Protection

It has been known for many years that excessive exposure to bright sunlight on snowfields leads to snowblindness. Eskimos have avoided this for centuries by making goggles out of bone with small slits in them that reduce the overall amount of light reaching their eyes. Within the last 25 years, much research has been done concerning irradiation on the eye.

In humans, the eye has evolved into an incredibly sophisticated organ whose neurophysiologic responses to photons in a certain portion of the electromagnetic spectrum provide a constant detailed map of our immediate environment. The action spectrum for this response lies primarily within the 400-700nm wavelength range. This range, therefore, is called the visible spectrum or "light". The maximum of the eye's spectral response corresponds roughly to the maximum of solar spectral radiance (555nm). In mountaineering, the portion of the electromagnetic spectrum responsible for snowblindness ranges from 280 nm to 400 nm.[4] With increasing elevation, shorter wavelengths of radiation are absorbed by the ozone layer. Increasing altitude, therefore higher intensity of electromagnetic energy reaching the eye, and reflectance off the white snow of this intense energy contribute to conditions for which our eyes weren't designed, thus damaging them and leading to photokeratitis.

The clinical signs of photokeratitis follow a characteristic course. After exposure, there is a period of latency varying more or less inversely with the amount of exposure. The latent period may be as short as 30 minutes or as long as 24 hours, but it is typically 6 to 12 hours.[7] Conjunctivitis, often accompanied by an erythema of the skin surrounding the eyelids, is associated with the sensation of a foreign body or "sand" in the eyes, varying degrees of photophobia, lacrimation, blepharospasm, ciliary injection, and aqueous flare. Corneal pain can be very severe. The individual is usually incapacitated for some period of time. These acute symptoms usually last from 6 to 24 hours, but in most cases all discomfort disappears within 48 hours.[7] Very rarely does exposure to sunlight result in permanent damage. Unlike the skin, the ocular system does not develop tolerance to repeated ultraviolet exposure.

The cornea is the first and principal absorber of ultraviolet radiation below 310 nm, the spectral region of the maximum UV-induced injury to the eye. Much of the research has been concentrated on this region. The UV is often divided into UV-A (320-400 nm), UV-B (290-310), UV-C (200-290).[15] A summary of corneal histologic changes exposed to the above region with a medium pressure quartz mercury lamp on rabbit corneas is as follows:

1. After four (4) hours of exposure, the effects consist mainly of occasional swelling of the squamous or basal epithelial cells. The endothelium and stroma are normal.

2. After six (6) hours, a large number of epithelial cell nuclei stain red with eosin, and the basal cells are widely spaced, indicating edema. The most superficial cells of the stratified squamous epithelial layer become irregular in arrangement.

3. These changes progress and become most noticeable after 12 hours. In some epithelial cells, granules appear to fill the entire nucleus, which is usually surrounded by a vacuole-like space. In contrast, other cells remain normal. Subsequent desquamation occurs in the central area of the cornea. The nuclei of the stroma or keratocytes stain deeply with methylene blue and begin to fragment.

4. These effects continue to increase in severity up to 16 hours after exposure, at which time swelling of the lamellae or collagen fibers of the stroma is apparent.

5. After 24 hours, the lamellae in the stroma are still swollen, and the endothelium shows some abnormal staining similar to that of the epithelium but they do not exfoliate.

6. The reparative process begins approximately five (5) days after exposure. The epithelial cells begin to assume again an orderly arrangement, and the changes reverse slowly until seven (7) days after exposure the cornea is essentially normal again.

Some more comments may be of interest. Damage is often attributed to UV destroying the nucleus and inhibiting the healing process by breaking down chromosomes.[6] During the latent period many biochemical changes occur.[4]

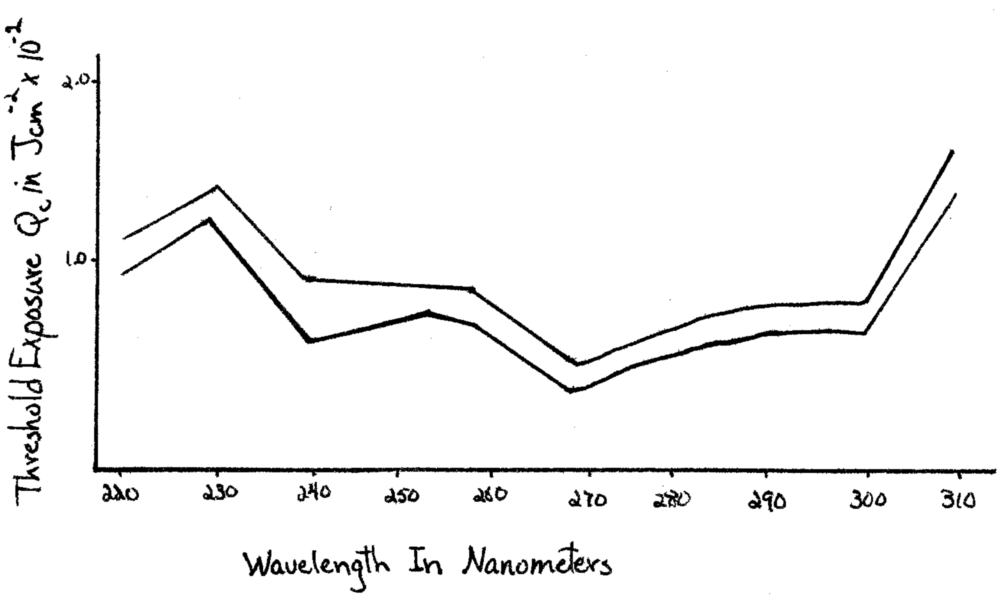
While it seems clear that exposure to UV-B wavelengths of sufficient intensity will cause permanent lens opacities, it is still in doubt whether or not UV-A of solar intensities will do the same, immediately or over a period of time. According to Pitts, radiation above 325 nm with an exposure of 59 J/cm^2 did not cause transient opacities.[18]

The UV-B seems to accelerate the aging process of the lens by changing soluble crystallines into insoluble crystallines, although the UV-A entering the eye is not enough to cause permanent damage.[15] So, even though the potential for lens changes exists in the human eye, the conditions existing under mountaineering circumstances do not cause lens opacities even though it is the lens that absorbs most of the UV-A entering the eye.[15,26]

Absorption of radiation by the cornea and lens of the human eye is such that very little radiation of the wavelengths shorter than 390 nm reaches the retina.[5] Only rarely could UV-A induce photochemical lesions in the retina in man.

From the results of these animal studies, I have extrapolated data so as to provide protection criteria and safety measures against ultraviolet radiation.[16] The setting of such standards is complicated because experimental data is often inadequate. So, considerable latitude exists as to the hazards of UV exposure.

Proposed human ultraviolet limits. The lower curve presents the threshold exposure for the human. The upper curve is 20% above threshold and indicates the level of ultraviolet required for discomfort and incapacitation.



The most widely accepted standard for exposure to conventional UV sources is that proposed by the National Institute for Occupational Safety and Health(NIOSH),[13] although other standards have been proposed. In the 320-400 nm (UV-A) region, a maximum total exposure of 1.0 J/cm^2 for periods less than 1000 sec (about 17 minutes) and a maximum UV-A irradiance of 1.0 mW/cm^2 for periods greater than 1000 sec are allowed. For example, noontime solar UV-A irradiance has a limit of 5.0 mW/cm^2 for long exposure; the maximum allowed exposure dose is 1.0 J/cm^2 in about 3.5 min.[15] In this case the NIOSH standard seems to be fairly conservative. However, for an exposure of 1 mW/cm^2 over eight hours, this is sufficient to cause sunburn in a fair-skinned individual. Although adequate biologic data is missing, an exposure standard is recommended, but may reflect some uncertainty.

It may be interesting to note how the NIOSH standards were determined.[19] The concept of the relative effectiveness of the action spectrum provides a convenient method for computing safe exposure times and the allowable transmittance of optical protective devices. The data required to calculate safe exposure criteria include the spectral irradiance of the source, the spectral transmittance of any optical media before the eyes, and the relative effectiveness of the

UV action-spectrum threshold. The relative effectiveness can then be calculated by selecting the lowest threshold values. The total relative effective irradiance for the lens or cornea may be calculated from the equation:

$E_{(wavelength_1 - wavelength_2)} = \sum ETW\Delta\lambda$ where $E(w_1-w_2)$ is the total irradiance for the lens or corneal action spectrum wavelength range, in Wcm^{-2}, E is the spectral irradiance of the source, in Wcm^{-2}, T is the spectral transmittance of the optical media, in decimal form.

W is the relative effectiveness of the action spectrum, and $\Delta\lambda$ is the waveband interval of the spectrum.

The safe exposure duration T is given by

$$T = \frac{H_W}{E(w_2-w_1)}$$

where H is the radiant exposure threshold for the cornea or lens. It is easy to see that there are many variables that need to be taken into account.

Usually, protection against excessive solar irradiation is needed for two reasons. The first is fairly obvious, it concerns the harmful physiological changes that occur from ultraviolet irradiation. The second is concerned with an environment of high luminance. The optimum lighting for vision is about 400 foot lamberts. Comfortable vision is possible up to a level of

1400 foot lamberts.[20] More light or less light will reduce the acuity. 400 FL is the amount of light in open shade under a large tree in the summer. Since at higher elevations and in snow, luminances of 10,000 to 15,000 FL occur, one would want a pair of glasses that transmit no more than 5% of the light (eg. 5% of 10,000 = 500 FL). It should be noted that high luminance exists also under cloudy conditions.

Another aspect is that of protection against infrared (IR). Infrared ranges from about 760 nm to about 1000 nm. It seems that near infrared at the level of solar intensity does not damage the eye.[11] Infrared, however, is of concern in certain occupations involving heat such as glass blowing. Infrared also is of concern on sandy, bright beaches. Ocular discomfort has even been reported in an arctic environment when the average light transmitted is less than 0.8 that in the IR.[11]

Lenses

There are may types of sunglasses on the market today. Thus, it is difficult to choose a pair of glasses designed to shield the eyes from radiation rather than to satisfy the fashion whims of the wearer. The problem is that many commercial sunglasses have UV windows.[18,10,2,8,23] This means that damaging UV is allowed to pass through the lens and is absorbed by the eye. Sometimes the situation is even worse than if the person would not be wearing sunglasses in the first place. The eye becomes uncomfortable in high-intensity visible light causing relief to be sought in the shade. Wearing lenses that attenuate the visible light while transmitting the UV enables the eye to function in a bright environment for a longer period of time, consequently increasing the total UV dose received by the eye. The second effect is caused by the eye's pupil. The attenuation of visible light by sunglasses will cause the pupil to dilate. This compensates in part for the attenuation, thus the retinal illumination is not reduced by the same factor as the attenuation of the sunglasses. If the glasses do not attenuate the UV sufficiently while blocking the visible, the eye receives more UV than without glasses. Good protection against UV is provided by ophthalmic crown, plastic CR-39 or several glasses such as Neophan (Auer-Gesellschaft, Germany).

An interesting aspect of sunglasses is their color. In principle, sunglasses can have any color. But, in practice people like their sunglasses to be of a particular color. Two aspects affect this choice of color. The first involves the field of syntonics or the effect on physiological mechanisms and perception. For example, blue tends to be a cool color, while red is a warm color, and grey is a neutral one.

Tints, the second factor, are produced by adding various metallic oxides to the mixture from which the glass is made. The absorption of UV is increased by the use of cerium oxide or ferrous oxide, which also absorbs IR.[9] These compounds produce a brown and a green color, respectively, and reduce the total transmission to an acceptable level. It should be pointed out that these are not the only chemicals that reduce the amount of UV transmission. Lenses that absorb UV without visible light attenuation are for example, Kromatone, Cruxite and Viopak.[9] The major disadvantage of these tints is that they are not of a uniform gradient density. This means that if the patient requires prescription glasses, the lens does not have the same transmission throughout. In a myope, the lens is lightest in the center and darkest at the edges, a highly undesirable feature.

In order to avoid this, coatings can be applied to the lenses. This also reduces the transmission of the UV and visible light to the required levels. A disadvantage to a coating is that it is susceptible to scratch marks, even though glass lenses have less of this tendency than plastic lenses. This is the reason I would not recommend a mirror, or UV absorbing coating for mountaineering lenses.

Since climbing is an athletic sport involving exposure to falling objects, some precaution should be taken concerning impact resistance. At the present time the standard for impact resistance is known as the Z.80 Ophthalmic Lens standard. All ophthalmic glass lenses are impact-resistance treated either chemically or by heat. Dress eyewear must have a minimum thickness of 2 mm at the thinnest point, with the exception of strong plus powers which usually have an edge thickness of 1.8 mm. These glasses are checked by dropping a 5/8 in. steel ball weighing 0.56 oz. from a height of 50" to the horizontal surface of the lens.[1]

Impact-resistant occupational lenses are designed for industrial use. The standard specifies that they need to be 3.0 mm thick at the thinnest point, with the exception of strong plus powers where a 2.5 mm edge thickness is considered adequate. To test for strength a 1 1/8 in. steel ball is dropped from height of 50 in.[1] These lenses are available in UV-protective tints and are highly recommended for use in mountaineering. The major disadvantage of these lenses is their weight, so the frames must be comfortably designed.

Besides tint there are other aspects to glass lenses that need to be considered. Many people seem to be concerned about whether or not their glasses should be polarized. Polaroid sunlenses are made from films of polarizing material laminated between clear or lightly tinted glass or plastic. The material consists of nitrocellulose packed with ultramicroscopic crystals of herapthite, all oriented parallel to one another. Their use is in blocking light that has been partially plane polarized by reflection off a snow or water surface. If the crystals are oriented horizontal, they provide a maximum blockage of glare coming from a surface that is horizontal. In water sports this is acceptable. However, since polaroid transmits UV, its use in mountain climbing is not recommended.

Photochromic lenses are made of conventional silicate glass with silver halide crystals added to it. The crystals are small enough not to scatter visible light. The crystals darken under irradiation in the spectral range of 300 to 400 nm with maximum activation at about 350 nm. The glass also has a tendency to work better in cold weather where it darkens more. This makes the lens sound like a good choice for mountaineering glass. However, the transmission (20% to 90%) is still too high.

Plastic lenses may be a misnomer for the CR-39 lenses used today in ophthalmic prescriptions. A CR-39 lens is very rigid and any desired modification must come through grinding or cutting, yielding a lens that behaves much like glass. However, there are many significant differences that need to be brought up.

Most important is that CR-39 has a specific gravity of 1.32, while glass has one of 2.5[9]. In other words, plastic lenses should weigh about one half of that of glass lenses. A plastic lens, though, weighs a little more because its refractive index is lower (1.5 versus 1.523 for glass). This means that a plastic lens will have to be slightly thicker than its glass counterpart. Still, plastic lenses are about 40% lighter than glass lenses. In climbing, weight is of great concern. This usually makes no difference except where a high minus lens is needed. As far as light transmission is concerned, CR-39 performs quite well with UV. CR-39 NOIR lenses provide good IR absorption and may accept tints. This might be a good mountaineering lens if the UV transmittance is that of normal CR-39 lenses.

Also, plastic lenses can be tinted in uniform density so as to reduce light by a specified amount throughout. This is particularly valuable for myopes where the center should be as dark as the periphery.

As far as impact, tensile and compressive strength are concerned, CR-39 "gives" more than glass, and will delay fractures from impact. When a plastic lens does break, the fragments are blunter, and fly off at a lower velocity. Also, plastic seems to maintain its strength quite well in the cold. This has led to theoretical conclusions that a CR-39 lens will protect a person better than the toughest glass lens.

Plastic lenses are more resistant to fogging than glass lenses. This is of course of prime concern in mountaineering. An interesting misconception has been in pamphlets stating that the specific heat of plastic is low, and that this is one of the advantages of plastic lenses over glass lenses with respect to fogging. The specific heat of CR-39 is 0.55 and that of glass is 0.20 which is much lower. This should make glass more resistant to fogging than CR-39, it isn't.[9] Resistance to fogging is caused by temperature changes that are related to the thermal conductivity, not specific heat, which ususally is reciprocal to the specific heat. Substances containing free electrons accept and transmit heat rapidly which means low specific heat and high thermal conductivity. Plastic has a higher thermal conductivity than glass.

For this reason, CR-39 is more fog resistant and is much more enjoyable to wear when it is cold, about 27 F. outside and and you're sweating from the exertion of going uphill and want to see through your glasses.

Another material can be used for glasses which is less scratch resistant than CR-39 but more impact resistant. This is polycarbonate. This, however, is not in wide use as yet, and not available such as CR-39 lenses are. Its application is mostly in industry.

Another important aspect of plastic and glass lenses should be a consideration of their quality. Glass lenses should be free from striae, bubbles and other defects such as chips and cracks. Usually glass lenses have the tendency to be free from warpage and peripheral irregularities. On the other hand, plastic lenses are often slightly too large for the frames they fit in and thus undergo warpage when inserted into the frames. This warpage can be seen in plano lenses if the concave side is held up beneath a fluorescent light and moved slightly so that reflection of the light is played across the lens. If waviness or distortion can be seen, then the lens is of poor quality. Also, if the glasses are held about a foot or so from your face and you look through them at a window or other straight edge, waviness or distortion can be seen in poor quality lenses.

An aspect of tinted lenses that should not be overlooked concerns the effects of these lenses on perception. In particular, visual acuity, color vision, contrast and dark a-daption. A recent study at Pacific University showed that the less the transmittance of the glass, the lower the acuity.[12] With decreased illuminance and decreased transmittance, the acuity is lowered to dangerously low levels. This sounds like it is fairly obvious; however, its importance should be considered when buying a pair of glasses with transmittance levels around 5%. Color vision and lens tints were considered in another PU research project completed at this time.[12] It was determined that tints in moderate amounts did not affect color vision in color-normal individuals. In color anomalous individuals, however it did have an effect. So, those persons with defective color vision should be aware of the possibility that tinted lenses could affect their color perception.

Dark adaptation is another factor affected when tinted lenses are not worn. This relates to the ability of the eye to see well at night. In other words, if tinted lenses are not worn under bright conditions, a person's night acuity will not be as good.

Several reports have approached the aspect of how the tinting of lenses affects the contrast of elevations and depressions in the snow.[24,3] The overall conclusions were that tints could affect the contrast of these bumps, however, not to the extent that it would decrease or increase their detection if acuity criteria were maintained. Or, in other words, wearing yellow lenses on a cloudy day will not increase the detection of irregularities in the snow.

The last aspect of lenses concerns the topic of contact lenses. Contact lenses have several advantages and disadvantages. There is one obvious advantage to the wearing of contact lenses. Contact lenses do not fog. The major disadvantage to contact lens wear is that contact lenses do not protect the eye and adnexa adequately enough from UV for use without another pair of glasses. Using two items where one will do unnecessarily complicates the situation. Contact lenses also do not give adequate protection against injury. They also may affect the eye where there is little oxygen in the air. This may make the eye susceptible to edema and other complications. So, wearing of contact lenses is an unnecessary complication of the problem.

In conclusion, lenses made out of CR-39 of ophthalmic quality are best. Of course their thickness should be adequate to follow the ANSI industrial guidelines. The color should be of a grey tint, and their transmission no more than 10% of the visible spectrum.

Frames

Frames come in many colors, styles and materials. For climbing either metal or plastic frames may be chosen. Most athletic models are plastic. With plastic frames, the lenses have less of a tendency to pop out if impacted than with metal frames. This factor is often enhanced by a large inside bevel holding the lenses in place and by a complete frame surrounding the lenses. As far as plastic frames go, the strongest material is nylon which will withstand much abuse before it will break.

Another aspect of frameselection concerns its comfort, fit and side protection. Some frames have rubber inserts for nose pads that are very comfortable especially when the glasses are banged while being worn. This is an aspect that adjustable nosepads do not have. Some of the best fitting temples are of the comfort-cable variety. If adjusted properly, these will be comfortable (cut to a length of about 1/8 inch from protruding behind the ear) and be able to ride out a hurricane. A small lightweight cord attached to the back of the glasses will hold these frames securely whenever they may be bumped or taken off for a few minutes.

Adequate sun protection also requires sideshields, preferably made of leather which breathes and conforms better to the face. Good ventilation against fogging is necessary.

There is one more aspect which I would like to discuss. This is the situation where a pair of glasses may be lost or broken and adequate protection is needed. In the worst case the person may even be snowblind. First, if one were to lose his glasses and need alternate protection, the best would be to use a pinhole (2-3mm) in diameter to see through. This could be made in may ways ranging from a slit in a credit card to holes in tape covering the eyes. A pinhole will give acceptable acuity which will be much appreciated by the ametrope. Eskimos used slits to protect their eyes for centuries from arctic glare and radiation.

In a case of snowblindness, the best is usually to do nothing. Cold compresses may help a little, but most healthy individuals will be back to normal within a few days. Two treatments have been used which definitely are not recommended. The first is applying a topical anesthetic to the eye to relieve the pain. Using an anesthetic will prolong the healing time and may even damage the epithelial layers of the cornea. Another treatment is to use topical corticosteroids to reduce the inflammatory reaction. Steroids also delay the healing action, so their use is not recommended. If at all possible, one should avoid getting snowblind in the first place. If this is not possible, the person must not reexpose himself until the damage is fully repaired.

Conclusion

In the case of mountaineering, a lens should have total absorption up to about 360 nm. The transmission above 380 nm should be no more than 10%. If at all possible, this level of transmission should extend into the near IR, above 780 nm. IR absorption, however, is not required for protection, merely for comfort. Conventional ophthalmic plastic lenses provide adequate protection against UV, but not for comfort in the IR. Glass lenses made with the right ingredients protect against IR and UV, but care should be taken to avoid buying glasses that attenuate the visible spectrum more than the UV. Lenses will fog less if they are made out of plastic. Photochromic glass is not suitable because its transmission is still too high.

Frames should be sturdy and lightweight. Nylon is a good material. Side shields are a must. This concludes my research into glasses for mountaineering considering the components that are necessary.

Bibliography

1. Practice for Occupational and Educational Eye and Face Protection, American National Standards Institute, New York, Z-87.1-1979.

2. Anderson W, Gebel K: Ultraviolet Windows in commercial sunglasses. Applied Optics, 16: 515-517, 1977.

3. Beattie B: Tinted CR-39 Lenses: Spectral transmissions and their variability. Pacific Senior Research, May 1980.

4. Biologic Effects and Measurements of Light Sources. Bureau of Radiological Health, FDA Doc. 768508, Washington, D.C. 1976.

5. Boettner E, Wolter J: Transmission of the ocular media. Invest. Ophthal., 1(6): 776-783, 1962.

6. Buschke W, Friedenwald S, Moses G: Effects of UV irradiation on corneal epithelium: Mitosis, nuclear fragmentation, post-traumatic cell movements, loss of tissue cohesion. J. Cell. Comp. Physiol., 26: 147-164, 1945.

7. Cogan G, Kinsey E: Action spectrum of keratitis produced by ultraviolet radiation. Arch. Ophthal., 35: 670-677, 1946.

8. Davis JK, Fernald HG: Prescription Sunglasses. Am. J. Optom. and Am. Acad. Optom., 46(7): 572-577, 1969.

9. Drew R: Professional Ophthalmic Dispensing. Chicago, Illinois, Professional Press, Inc. 1970.

10. Gebel K, Anderson H: UV windows in commercial sunglasses. Applied Optics, 16 (2): 515-517, 1977.

11. Hedbloom E: Ocular effects of IR in the arctic. Arch. Environmental Health, 2:85, 1961.

12. Jensen D, DePew K: The change in distance acuity as a function of cosmetic spectacle lens tints. Pacific Senior Research, May 1980.

13. Occupational Exposure to Ultraviolet Radiation. USDHEW, National Institute for Occupational Safety and Health (NIOSH), HSM 73-11009, Washington, D.C., 1972.

14. Palmblad T, Furakawa J: UV transmittance of major skier's sunglasses and goggles. Pacific Senior Research, May 1978.

15. Parrish J, Anderson R, Urbach F, Pitts D: UV-A. New York, N.Y.: Plenum Press, 1978.

16. Pitts, D G : The human ultraviolet action spectrum. Am. J. Optom. & Physiol. Optics, 51(12): 946-960, Dec., 1974.

17. Pitts D: The ocular ultraviolet action spectrum and protection criteria. Health Phys., 25: 559-566, 1973.

18. Pitts D, Cullen P: Ocular UV effects from 295-335 nm in the rabbit eye. DHEW (NIOSH) Publication No. 77-130, Division of Biomedical and Behavioral Science, Cincinnati, Ohio, 1977.

19. Pitts G, Cullen P, Hacker A: Ocular effects of near ultraviolet radiation: Am. J. Optom. Physiol. Optics, 54(8): 542-549, 1977.

20. Richards, O: Sunglasses for eye protection. Am.J. Optom. Physiol. Optics, 48: 200-203, 1971.

21. Tapaszto I, Vass Z: Alterations in mucopolysaccharide compounds of tear and that of cornea's epithelium, caused by UV radiation. Ophthalmologica, 158: 343-347, 1969.

22. Toda L, Newman D: The effects of colored lenses on color vision. Pacific Senior Research, May 1980.

23. Walker J: Ultraviolet windows in sunglasses. Nature, 266(7), April 1977.

24. Wyszecki G: Theoretical investigation of colored lenses for snow goggles. Soc. Oph. Am., 46(12): 1017-1074, 1956.

25. Zigman S, Schultz J, Yulo T: Possible roles of near UV light in the cataractous process. Exp. Eye.Res., 15:201-208, 1973.

26. Zigman S, Vaughan T: Near UV light effects on the lenses and retinas of mice. Invest Ophthalmol., 13: 462-465, 1974.